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ABSTRACT

This multiple case study examined the co-authorship process in two research laboratories of different university science departments. The study focused on five writing teams, one in Biochemistry and Microbiology and four in Earth and Ocean Sciences. The role of the researcher supervisor, the role of the student (graduate and post-graduate), the interaction of the supervisor and the student, the activities and processes inherent in the co-authorship process, and the student's expertise, scientific writing, and entry into an academic discourse community were documented. Multiple sources of data and methods were used to document the activities and processes in the co-authoring of research reports; the alignment between the students' and their research supervisor's beliefs about writing; and whether co-authorship helps the student become an expert science writer. Participants were given a questionnaire to ascertain their respective background experiences in science and their beliefs about science writing and followed through the five-month drafting process of a research report manuscript. Meetings between research supervisors and students were observed and audio-taped, and field notes and reflective notes were taken. Edited drafts, including research supervisor's suggestions and students' responses, were collected. During their writing or soon thereafter, students were given part two of the questionnaire to establish the methods they used when they wrote. Finally, the participants were asked to reflect on their co-authoring experiences and to suggest any other activities that would aid students (research supervisors' response) or themselves (students' response) in becoming proficient science writers. Several activities and processes were found to be common across all co-authorship teams, including aspects of planning, drafting, and revising. Habits of mind, beliefs about the nature of science, and abilities to communicate the big ideas of science were evident in these activities and processes. Elements of scientific and writing expertise, facets of enculturation into scientific research and discourse communities, academic civility, and the dynamics of collaborative groups also were apparent. Audience and journal selection were surpassed in importance only by the writers' perceptions of the rigor of their scientific claims. Graduate and post-graduate students' beliefs about science and the role of science writing agreed with those of their graduate supervisors. There was healthy tension and mutual respect in the research groups as they attempted to make sense of science, report their results clearly and persuasively, and shared the responsibilities of expertise. The findings of this study indicate that co-authoring a research report is an authentic and meaningful learning

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experience that helps students learn to write like scientists. (Contains 70 references.) (Author/MM)

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Learning to Write Like a Scientist

Marilyn K. Florence
Marilyn K. Florence Writing and Editing
Victoria, British Columbia, Canada
mkflorence@shaw.ca

Larry D. Yore
University of Victoria
Victoria, British Columbia, Canada
lyore@uvic.ca

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Abstract

This multiple case study examined the co-authorship process in two research laboratories of different university science departments. The study focused on five writing teams, one in Biochemistry and Microbiology and four in Earth and Ocean Sciences. The role of the research supervisor, the role of the student (graduate and post-graduate), the interaction of the supervisor and the student, the activities and processes inherent in the co-authorship process, and the student's expertise, scientific writing, and entry into an academic discourse community were documented. Multiple sources of data and methods were used to document the activities and processes in the co-authoring of research reports; the alignment between the students' and their research supervisor's beliefs about writing; and whether co-authorship helps the student become an expert science writer. Participants were given a questionnaire to ascertain their respective background experience in science and their beliefs about science writing and followed through the five-month drafting process of a research report manuscript. Meetings between research supervisors and students were observed and audio-taped, and field notes and reflective notes were taken. Edited drafts, including research supervisors' suggestions and students' responses, were collected. During their writing or soon thereafter, students were given part two of the questionnaire to establish the methods they used when they wrote. Finally, the participants were asked to reflect on their co-authoring experiences and to suggest any other activities that would aid students (research supervisors' response) or themselves (students' response) in becoming proficient science writers. Several activities and processes were found to be common across all co-authorship teams, including aspects of planning, drafting, and revising. Habits of mind, beliefs about the nature of science, and abilities to communicate the big ideas of science were evident in these activities and processes. Elements of scientific and writing expertise, facets of enculturation into scientific research and discourse communities, academic civility, and the dynamics of collaborative groups also were apparent. Audience and journal selection were surpassed in importance only by the writers' perceptions of the rigor of their scientific claims. Graduate and post-graduate

students' beliefs about science and the role of science writing agreed with those of their graduate supervisors. There was healthy tension and mutual respect in the research groups as they attempted to make sense of science, report their results clearly and persuasively, and shared the responsibilities of expertise. The findings of this study indicate that co-authoring a research report is an authentic and meaningful learning experience that helps students learn to write like scientists.

Introduction

Language is an essential part of contemporary scientific inquiry. The rhetorical nature of science requires scientists to use language, both to respond to their audience's feedback and to refine, revise, and reconstruct their knowledge claims as argument (Yore, 2001). Locke (1992) contended "[language] is not merely the empty vessel into which the contents of scientific thought is poured" (p. ix). Norris and Phillips (2001) asserted that reading and writing are essential parts not only of the scientific conversation, but also of doing science:

> [R]eading and writing do not stand in a functional relationship with respect to science, as simply tools for the storage and transmission of science. Rather, the relationship is a constitutive one, wherein reading and writing are constitutive parts of science, or, to view the relationship in the other direction, science is in part constituted by reading and writing. (pp. 7-8)

Individuals who aspire to become experts in science must have the ability to transform their findings into oral and written discourse. Initially scientists use oral and written descriptions of known events, predictions of future events, speculations of causality, and metaphoric models to help conceptualize science for themselves and their research groups (Haack, 2002a; Yore, Hand & Florence, 2001). They must then submit their conversations and text to the scrutiny of their peers, and subsequently be able to use peer criticism to refine and reconstruct their ideas. In accomplishing these goals, they are able to situate their work within existing scientific knowledge by addressing conceptual voids and expanding boundaries of canonical science, and to situate themselves within the science community.

Initiation into a discourse community -- enculturation-- is a crucial event in an academic's career. Bazerman (1992) noted "each newcomer to a field must come to understand, cope with and place himself or herself within the evolving conversation" (p. 66). Few studies have investigated practical means of developing writing expertise in novice science writers and inculcating these novices into the membership of a science discourse community during graduate and post-graduate programs. The purpose of this multiple case study is to determine how graduate and post-graduate student writers, one

in biochemistry and five in earth and ocean sciences, become encultured into their respective discipline-specific discourse communities (Florence, 2001). How do these novice writers learn to write like scientists, thus facilitating full entry and acceptance into their respective disciplines? The multiple case study focuses on a single enculturative activity for each writer, namely the co-authorship of a journal paper with his or her research supervisor.

Background

The exploration of the process of gaining membership in an academic science discourse community was developed on a foundation of science literacy, context and nature of language in science, expertise and expert communities, the expert science writer, enculturation in expert communities. Enculturation of novice scientists into these elite communities is a lengthy process that starts early in university studies and continues into the early stages of their academic careers. This study documents the middle period of this process during their graduate and post-graduate studies.

Science Literacy

Norris and Phillips (2001) described two senses of literacy: "In its fundamental sense, literacy means being able to read and write. In its derived sense, literacy refers to being knowledgeable, learned, educated" (p. 3). Applied to the notion of science literacy, a fundamental sense of literacy would equate to the ability to read and write in science, while a derived sense would indicate knowledge of and learnedness in science, in that the person could construct, apply, and criticize science in a pragmatic context. Norris and Phillips argued that individuals require both senses of literacy to be considered science literate; the conceptual fruits are not fully realized without the ability to inform and persuade others about these ideas. Conversely, comprehending oral and written messages about science cannot be fully understood without some prior knowledge about the nature and content of science.

Science literate individuals should have "the ability to share ideas and information with fidelity and clarity, and to read and listen with understanding" (AAAS, 1993, p. 138)

and participate fully in the broader debates about science, technology, society, and environment issues (CMEC, 1997; NRC, 1996). Unfortunately, many secondary and university students of science are unable to make defensible pragmatic interpretations of text (Norris & Phillips, 1994; Phillips & Norris, 1999). Flower (2000) stated:

> It is generally agreed that a science-literate person possesses a basic vocabulary of scientific concepts and terms, knowledge of the processes of science utilized to test our models for making sense of the world, and an appreciation of the effect of science and technology on society, to a degree sufficient to participate in dealing with the increasingly large number of science- and technology-laden public policy questions we face. (p. 38)

Flower's science-literate person is an informed, critical thinker and an astute decision maker, and is thus able to participate fully in public debate of scientific issues.

Hand, Yore, and Prain (2001) described science literacy as "the cognitive abilities and emotional dispositions to construct science understandings, the big ideas of science, and the communications to inform people about these big ideas and to persuade them to take informed actions" (p. 105). Cognitive abilities and emotional dispositions comprise the plausible reasoning and habits of mind needed to understand and apply the ontological assumptions of science and the epistemological criteria of science knowledge. Volkman and Eichinger (1999) referred to habits of mind as a way of thematically representing the personal and social qualities of doing: curiosity, openness, skepticism, and communication. They pointed to the essential nature of communication in demonstrating habits of mind: "As new ideas are communicated through presentations, papers, and journal articles, scientists continue to exercise the habits of curiosity, skepticism, and openness. As new ideas are tested, the community judges their merit" (p. 144). Perkins, Jay, and Tishman (1993) listed dispositions as one of the constituents of good thinking. Good thinkers possess mindfulness, invest mental effort, and take intellectual risks. "In general, dispositions can be defined as people's tendencies to put their capabilities into action. Mindfulness can be considered a disposition because it has to do with how disposed people are to process information in an open, alert, flexible way" (p. 75).

The big ideas of science include major unifying conceptions of science and beliefs about the nature of science (Hand, Prain & Yore, 2001). Lederman (2001) dealt with conflicting philosophies about the nature of science by positing that there was some agreement across views of science in that there were three viewpoints: science as induction -- just give me the facts; science as falsification -- just give me the imperfect facts; and science as relativistic -- my facts are as good as yours. Science as induction equates scientific knowledge with truth. This perspective is associated with an absolutist view of science, wherein knowledge is confirmed through sensory evidence or the power of intellect. Science as falsification is commonly described as an evaluativist view of science. The evaluativist viewpoint recognizes that scientific knowledge is temporary and based on explanations that best fit the warrants and evidence at hand. Science as relativistic is commonly referred to as a postmodern viewpoint in which knowledge is a construct of culture, society, and history. Postmodernists' explanations of science reflect lived experiences, personal beliefs, and the socio-political context of the day, dealing with issues of power, gender, class, race, ethnicity, and sexual orientation. Individuals construct their own knowledge of science, based on their own personal criteria. The postmodernist viewpoint assumes that all knowledge claims and interpretations are equally valid and therefore should not be judged by external agents. An understanding of these competing views of science is one of the components of science literacy (NRC, 1996; Yore, Hand & Florence, 2001).

The final constituent of science literacy, ability to communicate, includes the effective expression of claims, evidence, and warrants, which underlie knowledge building. Hjørland and Albrechtsen (1995) asserted that effective communication required an easily interpreted and socially based language of science. They argued that from the absolutist perspective, language constitutes labels and has no "contributing role in the perception of reality, but is functionally limited to communicating already established knowledge in the individual" (p. 408). Therefore, scientific language is detached from social or cultural considerations. Hjørland and Albrechtsen argued that a more modern, holistic view recognizes "the importance of language in the perception of reality, thereby introducing a historical, cultural, and social dimension in the theory of science. Reality cannot be understood naively by the unprepared and isolated subject. It

is the knowing subject, who is formed by history and culture, including the concrete development in specific knowledge domains, who has the possibility to perceive the reality" (p. 408). Hence if language is used to construct science knowledge, then knowledge must be influenced by, though not entirely dependent upon, the society in which the language exists.

Symbolic representations of data, ideas, and patterns of events support science inquiry; for instance, some forms of representation such as arabic numerals, figures, and graphs make interpretations of data more efficient and some labels, metaphors, and analogies stimulate clearer conceptions and understanding of natural phenomena (Haack, 2002a, 2002b; Yore, Hand & Prain, in press). Haack (2002b) metaphorically described science as doing a giant crossword puzzle, with the clues as external guides for inquiry that yield evidence to support speculations and the partially completed puzzle as the canonical science that augment evidence and constrain speculations. Incorrect entries in the central core of the puzzle lead to several and critical misinterpretations of related clues and unresolved future difficulties. Incorrect entries or the edges of the puzzle cause minor difficulties. Resolution of central errors may lead to major restructuring of the total cross-word solution, while resolution to exterior errors may lead to minor changes or redirection of future inquiries.

Context and Nature of Language in Science

Bazerman (1998) makes a case for a rhetoric of science, first noting that some rhetoricians and scientists would see science as "knowledge that rises above the situated and purposeful use of language" (p. 382). He stated:

> Within the bounded discursive world, of science, an intertext of cited works or a literature defines a gradually transforming discursive space within which new claims vie for acceptance, judged by an epistemic court of insider specialists. This enclosed communication system must then represent itself and its knowledge outward to the other public realms, to spread its influence, to petition for resources, and to establish and maintain its boundaries and authority. So a rhetoric of science can study an internal discourse of claim making, a socially contentious discourse of boundary creation and maintenance, and an outward-facing, interest-driven discourse of professional representation. (pp. 383-384)

Effective communicators in and of science must seek to understand more about the audiences within their professions. They must be aware of the makeup and the socio-political context – the culture – of their discourse communities (specialty discipline, general academic, classroom, popular media, etc.). They must be cognizant that the community's goals and values exist within this space (Beaufort, 2000).

Broad knowledge of the discipline's culture helps the scientist appraise the rhetorical situation and strategize the best ways to communicate ideas. Flowerdew and Miller (1995) defined disciplinary culture as the "theories, concepts, norms, terms…of a particular academic discipline.…[P]erhaps the most obvious way to recognise a discipline is through its specialized vocabulary" (p. 366). Harrison and Stephen (1995) argued that disciplinary discourse communities had special ways of knowing, believing, and persuading. "The fact that such conventions are held in common means that experienced writers within the discourse community are able to draw upon them for knowledge about what will count as appropriate language, appropriate evidence, and appropriate reasoning" (p. 595). The ontology, epistemology, traditions of evidence, warrants, and claims, conventions of argumentation, procedures of inquiry, and problem focus demarcate science as a unique discipline (Haack, 2002b; Hand, Prain & Yore, 2001).

Authors of scientific research reports for peer reviewed journals most often situate their findings through citation of existing research that "establishes the intertextual linkages that diachronically connect scientists' laboratory activity to significant activity in the field, and thus serves to establish a narrative context for the study to be reported" (Berkenkotter & Huckin, 1995, p. 47). Intertextuality reflects the interdependent structure of scientific knowledge that stresses conceptual networks rather than isolated concepts. Chaopricha (1997) described the valued role of citation in writing as "scholarly bricklaying" (p. 16). Static inquiry is directed at new claims that fill voids within or address conceptual nodes on the edges of the established knowledge network described by the intertextual background, while dynamic inquiry redirects the growing knowledge network. It is these major shifts in or restructuring of the conceptual network that require the most compelling evidence, tightest argument, and persuasive reporting, and receive the greatest scrutiny by peer reviewers.

Nonetheless, the intertextualization of current findings within established results and new text within published texts does not necessarily guarantee the scientific writer credibility within the community. Writers must seek to insinuate their findings into the community with full regard to the extensive power of the discipline's "gatekeepers" (Burton & Morgan, 2000, p. 431). Editors and peer reviewers are often the first to encounter this metadiscourse-laden text, and they are generally considered to be the most critical readers of academic texts. Writers negotiate with editorial referees, the disciplinary gatekeepers, to have their claims included in authorized and canonical science.

Expertise and Expert Communities

Those in science who wish to become expert science writers or perhaps join the powerful few who act as disciplinary gatekeepers need to understand the nature of expertise and expert communities. In general, growth in expert communities takes the form of progressive problem solving in response to pressing issues of the discipline and the need for increased competence. Yet, increased competence involves more than stacking additional skills and knowledge on pre-existing competencies (Holliday, Yore, & Alvermann, 1994). Expertise appears to involve a complex interplay of cognitive abilities, emotional dispositions, strategies, metacognitive awareness, executive control, domain knowledge, and discourse knowledge (Yore, 2000). The expectation that members will continuously use their unique talents to tackle new problems and acquire greater proficiency in their fields is inherent in expert communities, and such anticipation of growth leads to internal tension. The expert is not allowed to be comfortable with his or her current expertise, and, as a result, constantly pushes the boundaries of his or her knowledge and competence. In considering experts as learners, Daley (1999) and Patel, Glaser, and Arocha (2000) found that, when compared to novices, experts exhibited greater levels of self-regulation and metacognition. Experts showed more self-awareness and initiative and were more likely to deconstruct experience relative to the learning and practice environments. Holyoak (1991) indicated that experts use executive control of their thinking and actions to circumvent constraints by searching backward, in an iterative fashion, or forward, out of the box, in search of a new possibility. Experts are continuous learners: they are constantly testing their abilities to think critically and to solve

problems. Thus "for experts, the problems of insufficient prior knowledge never go away. ...The expert track of development keeps rising toward levels of increasing complexity of performance and understanding. This means that present knowledge is always superficial, simplistic, and fragmented relative to the knowledge the expert is trying to achieve" (Bereiter & Scardamalia, 1993, p. 175).

Experts' dissatisfaction with the status quo, their passion for disciplined inquiry, and their desire for cognitive growth are indeed what makes them experts: greater scope and extent of learning in any field of endeavour should lead to better understanding, which in turn could be expected to enhance expert performance. General and specific domain knowledge is necessary for membership in this elite community, but not sufficient: as experts acquire increased conceptual understanding, they also acquire flexibility, become more metacognitively aware, and gain greater executive control of this knowledge and its potential applications.

The Expert Science Writer

Carter (1990) argued that expert writers must possess both general knowledge of writing and domain-specific "local" knowledge of writing (p. 269), "neither the general nor the local perspective alone provides a complete picture of the complexity of writing" (p. 266). Bereiter and Scardamalia (1987) found that expert writers differ from their novice counterparts in the way in which they use writing. Novices use writing to tell knowledge, while experts use writing to construct, to build, or to transform knowledge. Experts use metacognitive awareness and executive control to integrate domain expertise and rhetorical expertise; the latter component is composed of strategies, conventions, traditions, and knowledge of their discourse community (Yore, 2000). Experts strategically move between the content domain and the rhetorical domain as required and with ease to effect knowledge building. Geisler (1994) supported the constructive and interactive relationships within and between domain and rhetorical knowledge, asserting:

> One of the most important lessons of recent scholarship on literacy in the professions is that whenever expert practice is truly present -- when knowledge is treated as something to be constructed rather than found -- both rhetorical process and domain content will necessarily be involved. (p. 228)

Scardamalia and Bereiter (1991) referred to this recursive action as a "dialectical process that serves to advance domain knowledge" (p. 190). Keys (1999) suggested that in managing this process, expert science writers are able to give attention to both the content and the rhetorical aspects of writing, while novice writers often become embroiled in the latter and neglect the former.

Klein (1999) described four interpretations of how writing could be used to enhance understanding: spontaneous utterance, forward search, genre-related, and backward search. The spontaneous utterance interpretation assumes that writing shapes thought at the point of formation; that is, the act of converting mental models and ideas into printed representations makes tacit understandings explicit. The forward search interpretation asserts that writers transform their ideas with ongoing analyses of their texts as they convert mental models and ideas to print and symbolic representations, such as figures and graphs, without the constraints of a specific goal or purpose. The genre-related interpretation maintains that the use of different function-form frameworks (genre) and knowledge of textual microstructures and macrostructures enables the writer to surface patterns of events, to identify relationships among ideas, and to clarify understanding of the embedded ideas not apparent in the mental models and ideas held in long-term memory. The backward search interpretation argues that setting and addressing rhetorical and conceptual goals allow writers to learn through writing as they monitor internal coherence; strength of argument; relationships among claims, evidence, and warrants; and attainment of their goals. Expert writers use backward search to "elaborate rhetorical goals of a writing task to accommodate the interests and knowledge of their audience, the personae they wish to project and the formal characteristics of the required text" (Klein, 1999, p. 243). Forward search, genre, and backward search interpretations are forms of knowledge building. Klein suggested that backward search may be considered the top-level strategy, and he contended that writers could bring in other strategies to support it (Klein, personal communication, 2000).

Scardamalia and Bereiter (1991) acknowledged that expert reading and writing involved "effortful problem-solving processes" and thus took time and mental resources, sometimes to the detriment of other work (p. 190). Yet they argued that the struggle was worthwhile:

> Somehow, experts in learned fields must contrive to do all three -- read, write, and do something to write about. ...It should help...to be aware of the synergistic possibilities of carrying out all three activities in ways to extend the limits of one's expertise, thus making it possible for all three to move to higher levels. (p. 191)

Yore, Hand, and Florence (2001) and Yore, Hand, and Prain (in press) identified characteristics, understandings, and practices of expert science writers. They used questionnaires and semi-structured interviews to document common attributes, values, beliefs, strategies, and criteria that university scientists use when they address different writing tasks and audiences, and to determine if there are associations among scientists' views of science and views of writing. The scientists described, implied, and demonstrated the knowledge, metacognition, and emotional dispositions associated with scientific expertise. They also showed expertise in writing for a scientific audience. They used writing to inform and persuade, and to establish themselves in the larger community. The participants noted that they used writing to clarify their ideas. Peer review also helped them improve their writing; in some cases, it was transformational and led them to construct new understandings of their work.

These scientists believed that science writing had to be judged first by the quality of the science it contained and second by the quality of the writing. Unlike the scientists in Yore, Hand, and Prain (in press) who appeared to hold absolutist views of science, the scientists in Yore, Hand and Florence (2001) expressed evaluativist views of science in which inquiry directed at specific problems, questions, or issues provided data that were used to temporarily describe and explain patterns of events in the natural world. These respondents tried to align their writing with their beliefs about science and technology; for instance, some would use only passive voice to indicate objectivity. A few expressed an interest in using active voice to acknowledge the presence and influence of the researcher; however, they also were aware of accepted practices, traditions, and conventions in their discourse communities. The scientists in both studies were very cognizant of their audiences. They used jargon as appropriate to target readers. Their choice of genre and style also was appropriate to their audiences. Some believed it was better to conform and be published, while others were willing to question and rebut peer reviewers and gatekeepers.

The science writers described in the Yore, Hand & Florence (2001) study all had supervised graduate students and many regularly co-authored with them. Indeed, many academic publications resulted from the collaboration of students and faculty in the laboratory and at the computer. All respondents had experiences in writing at the side of their graduate supervisors. Some had received mentoring in writing, and they had essentially learned how to write by reading copious published research reports and journal papers in their research areas. Others had read a great deal and also had been mentored by their supervisors. None described outstanding experiences as reported by other scholars (Luebes, et al., 1998); but these scientists would have appreciated more mentorship in writing and believed this attention could have provided them with valuable experience and greater perspective on scientific writing. In summary, these scientists recognized the importance of writing in publishing their results and in receiving research grants and awards, but few explicitly recognized the importance of writing in constructing new science ideas and insights. They further acknowledged the importance of giving their graduate and post-graduate students the most extensive, authentic, and constructive writing experiences possible.

Enculturation into Expert Communities

Newton and Newton (1998) described enculturation as a process whereby the novice learns what counts in a particular discipline. Both the cultural and epistemic components of enculturation involve the novice working alone or with an expert in a mentoring relationship. Self initiation into an expert community is a difficult and rare event, since an isolated individual has no way to discover the undocumented knowledge, traditions, conventions, and practices of the community and since the individual has no sponsor to advocate his or her membership. The expert provides domain knowledge through modelling and transmission, experience during activities, and encouragement and insider knowledge of the culture during interpersonal exchange (Perkins, Jay, & Tishman, 1993). Polson (1998) stressed that, ideally, advisors become occupational socializers, fostering not only academic identity, but also a sense of professionalism. Pole (1998) described the supervisory and advisory positions as interactive, growing to meet the needs of the students and to expand the competencies of the students and supervisor.

Jacoby and Gonzales (1991) studied interpersonal interactions about writing projects, conference preparations, and other projects in a university physics research team and found that the identities of 'novice' and 'expert' most assuredly were not static but "complex and dynamic constitutions of Self and Other brought about by and through interaction over time" (p. 151). They discovered that any team member could be "more knowing" or "less knowing" at any point in a discussion, depending on the team member's knowledge with respect to the topic being discussed (p. 152). Jacoby and Gonzales stated,

> [R]ather than viewing interactional behavior as the direct, unproblematic outcome of participants' particular hierarchical social identities, we view interaction as the locus wherein social identities are co-constructed, maintained, and modified with consequences for future interactions, even if participants come to the interaction with professionally ranked social identities and a history of past encounters with one another. (p. 174)

The pragmatics and operations of the research environment and collaborations appear to invest power and rank in every member of the group at different times depending upon the particular demands of the task.

Two interpretations of enculturation—cognitive apprenticeships (Brown, Collins, & Duguid, 1989) and legitimate peripheral participation (Lave & Wenger, 1991) —appear to have value in making sense of novice scientists orientation and acceptance into a science discourse community. Cognitive apprenticeship assumes academic learning delivered during an authentic practice of the science community. In this interpretation of enculturation, the master and the novice collaborate on a real activity and as a situation arises requiring inquiry process or domain knowledge not held by the novice the master provides the appropriate tutoring. Lave and Wenger (1991) proposed "learning as situated behavior" (p. 29) to describe a newcomer's movement toward full participation in a socio-cultural community. They stated:

> In our view, learning is not merely situated in practice -- as if it were some independently reifiable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived-in

> world...Legitimate peripheral participation is proposed as a descriptor of engagement in social practice that entails learning as an integral constituent. (p. 35)

Both interpretations of enculturation involve developing a collaborative, respectful, trusting environment where all participants can respond honestly without fear of reprisal. Trust between supervisor and student is arguably one of the most important elements in establishing constructive working relationships. "Trust is said to exist in an interactive context in which participants co-construct their relationship through verbal and non-verbal indexes in a way that is (a) mutually recognizable, and (b) mutually desirable" (Rudolph, 1994, p. 200). The products of an apprenticeship are considered "to be a socially co-constructed product of the interaction between the novice and the expert. Acquisition of the target Discourse is achieved through the complementary roles of interpreter and interpreted, whereas a bond of trust licenses the participants to carry on the acquisition/apprenticeship process" (pp. 200-201).

Enculturation must help the novice become acquainted with epistemic stances (ways of knowing) and identities (ways of being) of an academic discourse community. Newton and Newton (1998) pointed to the value of epistemological knowledge of a discipline: "Understanding, valuable in itself, can facilitate the construction of further understanding that, in turn, has its own generative potential....[which] enables effective, independent interaction with the world" (p. 339). Furthermore, sharing meaning with colleagues in respect to literature and professional language helps the academic establish his or her own cultural identity (Becher, 1989). It also serves to keep the academic's subject matter beyond the understanding of those outside of the discipline. These tactics, though not openly discussed, help maintain the exclusivity of the expert group. They create an atmosphere in which those on the periphery -- students for example -- become especially desirous of acceptance to the group. "Notice the subtle difference between the discourse of people who are established in the profession and those who are not -- particularly those without tenure. Certain liberties, risks, tones, and stances are taken by established insiders that are not usually taken by the unannealed. Discourse is power" (Elbow, 1991, p. 139).

Becher (1989) contended that admittance to the academic profession requires only the knowledge to share meanings, but also a "proper measure of loyalty and adherence to norms" (p. 25). Loyalty might well be expected, as membership has its privileges and obligations. "Writers in a disciplinary community are part of a discour tradition and are accountable to the discipline's past, to its shared concerns, and share knowledge" (Hjorland & Albrechtsen, 1995, p. 407).

Loyalty and adherence to norms tend to stabilize a discipline even in periods c dynamic change, as has occurred with the views of science in the last 50 years. Transition to full membership in a discourse community can be made easier for novic they have the opportunity to work closely with their advisors, established members o community. Belcher (1994) identified the benefits of novice student writers and exp faculty writers working together. "Collaborative relationships...offer a means of help students become risk-takers by giving them an insider's appreciation of both the reas and the rewards for writing up research" (Belcher, 1994, p. 32). Authentic, collabora writing experiences encourage growth and risk, make the implicit, explicit, and reflec interactive, constructive nature of writing. Belcher found that advisor and student collaboration on a research paper helped ensure writing success. Undoubtedly, part o this success was dependent on the scaffolding provided by the supervisor; however, Belcher found that students who were given responsibility and made their own decisi became confident and able to "negotiate the demands of some of the most advanced literate practices in their fields" (p. 23).

Recent studies of writing to promote disciplinary traditions and to enhance content learning have revealed collaborative approaches embedded in authentic conte inquiries can be beneficial. Chinn and Hilgers (2000) found that undergraduate scien and applied science instructors who acted as collaborators rather than evaluators chos assignments and instructed in such a way as to expose the students to situations that might occur in cooperative working communities. Students were more satisfied with this approach than they were with a traditional instructor-as-evaluator approach, as they were able to gain first-hand experience with authentic aspects of writing. Bunch (1995) undertook a study of co-authorship in a mathematics education program and found "feedback [students] received from the professor and from one another served the sam

purposes as that within the professional community -- response and engagement rather than correction and evaluation" (p. 30). Dysthe (1999) noted that the process of writing a masters thesis required students to develop a disciplinary identity and situate themselves within a discourse community. Yet they also must be made aware of other ways of writing. Dysthe postulated, "This presupposes an insight which their supervisors and teachers possess as experts, practitioners and writers in the field, but often lack at a conscious or metacognitive level" (p. 5). Dysthe argued that some knowledge of writing and texts is not discussed during graduate supervision and thus remains essentially unavailable to the student. Her study of faculty and graduate students in religious studies and administration/organization revealed that students had vague ideas about text and could not interpret text or lacked the language to discuss it. Effective supervision needs to make implicit knowledge about text and language explicit. Interestingly, Dysthe found that explicit discussions were perceived to have potential negative consequences because of learned helplessness and adherence to norms.

Prior (1995) considered the nuances of response between a sociology graduate student and her advisor (professor) in the construction of a conference paper. He traced the intermixture of the professor's and the student's words in the student's writing, and explored the extent to which the professor's words were authoritative or "internally persuasive" (p. 320). Intertextual patterns indicated that the student both incorporated and resisted the professor's written suggestions. Prior concluded "participation necessarily transforms as well as reproduces social practice" (p. 319). Chaopricha (1997) looked at just such a social interaction in her study of three novice writers (doctoral students) in a biochemistry research laboratory. Chapopricha found that "to be able to communicate with other members of the community, biochemistry writers have to understand how biochemists justify their beliefs socially, as well as how knowledge is established and maintained in the discourse community" (p. 1). Chaopricha looked closely the students' enculturation experiences with "expert" writers (biochemistry professors). She used in-depth interviews, stimulated interviews, and verbal protocols to collect her data. Chaopricha found *"coauthoring and conferencing to revise drafts in specialized discourse are efficient methods in supporting novice writers to achieve authority in structuring information for intertextuality and argumentation" (p. 166).*

Contemporary literacy involves more than reading and writing; it comprises the ability to think critically and to take action. Academic scientists represent the higher levels of science literacy in that they are expert inquirers, knowledge builders, and communicators within their specific discipline. Expert denotes a high level of critical thinking and metacognition; it also indicates that the individual has the capacity and emotional disposition to take action and the desire to continuously improve her or his competence. Expert science writers are comfortable within their respective discourse communities; they use their knowledge of genre and audience to construct new science ideas and insights. Expert science writers in academia further recognize their responsibility as mentors of graduate and post graduate students. Exemplars of science literacy, these research supervisors work with novice scientists to help them become productive researchers and expert writers in and of science. This multiple case study comprises an investigation of this process as it unfolds during co-authorship experiences of two expert science writers and their graduate and post graduate students. The research questions under study are:

1. What are the activities and processes inherent in the co-authorship of research documents?
2. How do the graduate student's or post graduate student's and the research supervisor's beliefs about writing agree or disagree?
3. Does co-authorship help the student become an expert science writer?

Methodology

This study utilized a multiple case study design in an attempt to explore a collection of bounded systems over time through detailed, in-depth data collection involving multiple sources of information (Cresswell, 1998, p. 61). Case studies cope "with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from prior development of theoretical propositions to guide data collection and analysis." (Yin, 1994, p. 13) Stake (1994) stated "researchers may study a number of cases jointly in order to inquire into a phenomenon, population, or general condition. We might call this a

collective case study. It is not the study of a collective but an instrumental study extended to several cases" (p. 237). Multiple case studies utilizing common questions, procedures, data sources, propositions, and analysis principles contribute to the development of assertions that apply to each case in the collection. Furthermore, the use of such anchors facilitate the generalizability of the results among case studies conducted by different researchers in slightly different bound systems.

Purposeful cases were chosen for this study because of the documented characteristics of the research supervisor participants from an earlier study (Yore, Hand & Florence, 2001). The two research supervisors chosen for the study were both well published, and were recognized as experts in their specific scientific fields. One supervisor participant served as a case-to-case connection to an earlier study of enculturation into the biochemistry discourse community (Chaoprichs, 1997). The student participants were chosen opportunistically, that is, their participation was based on their involvement in co-authorship activities with their supervisors at the time the study was undertaken and their willingness to volunteer. Even though the student participants had previously collaborated on journal papers, overall they were less proficient and experienced science writers than were their supervisors. They also were not fully accepted members of their chosen disciplines. Thus, the students were considered novice science writers for the purposes of this study.

Cases

The student participants were enrolled in a Master program (1 female), a Ph.D. program (2 males), and post doctoral fellowship study (1 female and 2 males). It is noteworthy that all the post doctoral fellows were educated at European universities and did not consider English as their first language. They were all proficient English speakers; in general, their writing could be considered as least as good as that of the average Canadian-born graduate student. A total of five advisor-student co-authorship teams were studied. Each team worked on different research reports for a peer-reviewed journal.

hemistry Team #1 (BT#1)

of co-authored publication: Protein microchemical and mass spectrometric
n of an endosymbiont GroEL as the major protein expressed in the midgut of
Glossina morsitans morsitans.

on (a pseudonym) is a research supervisor in biochemistry, specializing in
nistry and biochemistry of parasitic diseases, immunology of membrane
l immunodiagnosis of disease. The main focus of research in his laboratory
rface molecules of protozoan parasites, primarily African trypanosomes.
een a faculty member for more than 20 years. He publishes regularly in
ology and molecular parasitology journals, including Molecular and
l Parasitology and Parasitology Today. Cotton has received a great deal of
ntion in the popular press for his work on African sleeping sickness, and he
l to Africa on several occasions to conduct research and meet with

ne (a pseudonym) is a Masters student in biochemistry. She received a BSc in
biology at another Canadian university, with a specialty in parasitology, microbiology,
and marine biology. Rayne joined Cotton's laboratory in 1999. Her area of study is
parasitology, specifically interactions between African trypanosomes and the tsetse fly.

Atmospheric Physics Team #1 (AT#1)

Title of co-authored publication: "Forcing of the deep ocean circulation in
simulations of the last glacial maximum"

Alistair (a pseudonym) is a research supervisor in the earth and ocean sciences,
with an interest in the role of the oceans in climate change/variability; ocean/climate
modeling; paleoclimate; physical oceanography; and geophysical fluid dynamics. The
research in this laboratory focuses upon the large-scale ocean circulation and the role of
the oceans in climate, with a special emphasis upon three-dimensional numerical
modeling. Alistair has been on faculty for nine years; he was awarded a Steacey Research
Fellowship (1997-1999), a Canada Research Chair, and a prestigious Killam Chair (2002-
2004) and was elected a fellow of the Royal Society of Canada. He publishes regularly in
a number of climate and geophysical journals and on occasion in more widely circulated

journals, such as Nature and Science. Alistair's research also has been covered extensively in the popular press, and he has written several op-ed pieces.

Karin (a pseudonym) is a post doctoral fellow specializing in physical oceanography and climatology. After completing a doctorate in physics in Europe, Karin came to study with Alistair in 2000. Her principle area of study is climate modeling and ocean circulation changes.

Alexander (a pseudonym) is a post-doctoral fellow in climatology. He received his Ph.D. in Europe in climate physics. Alexander joined Alistair's laboratory in 2000, and his principle area of study is numerical modeling of the atmosphere-ocean system.

Atmospheric Physics Team #2 (AT#2)

Title of co-authored paper: "Trends in the diurnal temperature range in the CCCma coupled model"

Daniel (a pseudonym) is a Ph.D. student in climatology. He comes to Alistair's laboratory having received a B.Sc. (honours) in physics and math and an MSc in climatology from his current university. Daniel worked as a research assistant and teaching assistant during his undergraduate program. His dissertation focuses on changes in the global mean surface area temperature.

Atmospheric Physics Team #3 (AT#3)

Title of co-authored paper: "Importance of wind-driven sea ice motion for the formation of Antarctic intermediate water in a global climate model"

Victor (a pseudonym) is a research associate specializing in physical oceanography. He received a Ph.D. at a European university and came to Canada in 1999 as a visiting scientist at the Institute of Ocean Sciences. Victor joined Alistair's research group in 2000. His principle area of study is sea ice modeling and coupled ocean-ice-snow-atmosphere modeling.

Atmospheric Physics Team #4 (AT#4)

Title of co-authored paper: "Instability of glacial climate in an Earth system climate model"

Ryo (a pseudonym) is a Ph.D. student who comes to Alistair's laboratory with a Masters of Engineering (Mineral Resources) from an Asian university. Ryo's current

area of research is paleoclimate modeling with an emphasis on the climate changes and variabilities during the last glacial cycle (125,000 - 6,000 years ago).

Alexander: Alexander from Atmospheric Physics Team #1 is also a member of this co-authorship team.

Data Collection

Participants were given a questionnaire to ascertain their respective background experience in science and their beliefs about science writing. Research supervisor participants had answered these questions in a written questionnaire in the Yore, Hand, and Florence (2001) study. Participants were followed through the drafting process of a research report manuscript. Each time a research supervisor and a student or students met formally to discuss the process and product, they were observed and audio-taped with their permission. Informal meetings of participants and the resulting conversations that occurred in the laboratory were not captured on audio-tape but field notes were made. These informal discussions between the researcher and the students took place on occasion and afforded the opportunity to learn more about their backgrounds, their research interests, and their academic aspirations.

Field notes and reflective notes were taken at each meeting. Field notes included general descriptions of what went on in the meeting. Reflective notes included questions by the researcher to herself about the meaning of certain processes, as well as general observations about the participant's affect, body language, and other non-verbal behaviors. Edited drafts of research report manuscripts, including research supervisors' suggestions and students' responses, were collected. During their writing or soon thereafter, students were given part two of the questionnaire to establish the methods they used when they wrote; for example, did they use outlines, did they edit and revise, and so on. Finally, research supervisors were asked whether they saw changes in their students' writing, critical thinking, and metacognition during the co-authoring process. Both students and research supervisors were asked if they saw evidence of knowledge building or conceptual change in members of the co-authoring teams. They also were asked to describe their roles in the process and whether being observed affected their interactions.

Data Interpretation

Data from each questionnaire were entered in a word processing file. Questions were then grouped together (e.g., all of question one, question two, and so on). Transcripts were made of each audio-taped meeting. Drafts of research papers were compared and author's reactions, margin notes, and revisions noted. Final e-mail questionnaires were transferred to word processing files.

A data interpretation framework was developed using prepositional linkages and interpretive principles or themes abstracted from the literature review to establish a theoretical connection among data, evidence and claims (Lester & Wiliam, 2000; Yore, 2002). Each interpretive frame comprises (1) a research literature-based assumption, (2) a proposition of what is likely to be observed, and (3) several interpretive principles believed to be connected to the anticipated evidence. Each interpretive frame was connected to a specific research questions (RQ). Word files and draft manuscripts were searched manually for the presence or absence of supporting evidence in the form of specific words or phrases related to the seven propositions. Unexpected findings were documented for further exploration.

Interpretive Frame #1: Science Literacy (RQ #1, #2)

1. Assumption: In order to do science, scientists must have the cognitive abilities and emotional dispositions to construct science understandings. The personal and social qualities necessary to do science are referred to as habits of mind. They include curiosity, skepticism, and openness. These traits are also associated with critical thinking, which is manifest in mindfulness, investment of mental effort, and willingness to take intellectual risks.
2. Proposition: Members of a research laboratory, and specifically members of these co-authorship teams, would be expected to demonstrate habits of mind conducive to doing science, and to writing, revising, and submitting scientific papers for publication.
3. Interpretive principles: Curiosity, skepticism, openness, mindfulness, mental effort, and risk taking

Interpretive Frame #2: Nature of Science (RQ #1, #2)

1. Assumption: The big ideas of science often are manifest in beliefs about the nature, structure, and key knowledge claims of science. Conflicting philosophies about the nature of science have been dealt with by positing three viewpoints: traditional, modern, and post-modern (Yore, Florence & Hand, 2001).
2. Proposition: Each co-author is likely to have an unique view about the nature of science. These ontological and epistemological beliefs are expected to affect how co-authors conduct their research, how they craft an argument, and how they use language to express their findings.
3. Interpretive principles: Absolutist view of nature of science (traditional, realistic, positivistic), evaluativist view of nature of science (modern, naïve-realist interactive-constructivist), and relativist view of nature of science (post-modern idealist, radical constructivist view).

Interpretive Frame #3: Role of Writing in Science (RQ #1, #2)

1. Assumption: Writing is an essential part of doing science. Speaking, reading, and writing are constitutive as well as communicative and transmitive parts of science (Norris & Phillips, 2001). Those who aspire to expertise in any given scientific field must have the ability to transform their findings into text. They must be willing to submit the texts to their own scrutiny and that of their peers, and subsequently be able to use personal reflections and peer criticism to refine and reconstruct their ideas.
2. Proposition: Co-authors are expected to realize and respect the essential place of writing in their scientific endeavours and careers. They should be knowledgeable about the language of their disciplines, accepted genres, the role of citation, the use of hedging, the importance of audience awareness, and the value and restrictions of peer review.
3. Interpretive principles: Disciplinary language, genre and for-function knowledge, intertextuality and citation, hedging, audience, and peer review.

Interpretive Frame #4: Scientific Expertise (RQ #1, #2)

1. Assumption: Growth in expert communities takes the form of progressive problem solving determined by the pressing issues of the discipline and increased competence. Experts, as life-long learners, will continuously use their unique talents to address

self-imposed demands, tackle new problems, and acquire new competencies. Expertise features metacognitive awareness and self-regulation, as well as general domain and specialty knowledge, abilities, dispositions, and discourse knowledge.

2. Proposition: As highly regarded scientists in their respective fields, the research supervisors in these cases are expected to exhibit expert characteristics. They may be expected to display these characteristics in their conduct and in their work (laboratory and written).
3. Interpretive principles: Progressive learning, assimilation, knowledge building schema, self-regulation, metacognition, self-confidence, healthy intellectual tension, judgment, and risk taking.

Interpretive Frame #5: Expert Science Writer (RQ #1, #2)

1. Assumption: The expert writer possesses the ability to write in general, the rhetorical knowledge to write in her or his discipline, and the knowledge of the domain and specific discipline such that he or she may be considered an expert. Expert writers are transformers of knowledge, using metacognition to compose, to represent mental models and ideas, and to resolve contextual discourse problems. Expert writers of science emphasize good science first and good writing second.
2. Proposition: Co-authors in this study are expected to be able to write and to have discourse knowledge, domain knowledge, and metacognition appropriate to their respective disciplines. Their writing should help them transform their knowledge; this should be evidenced in choosing a genre, setting rhetorical goals, selecting language, resolving differences, addressing reactions, and reviewing and revising.
3. Interpretive principles: Discourse knowledge, domain knowledge, metacognition, persuasion, revision, rhetorical goals, genre selection, journal selection, and audience awareness.

Interpretive Frame #6: Enculturation into the Scientific Research Community (RQ #2, #3)

1. Assumption: Enculturation into a discipline entails learning its epistemology, conventions, traditions and practices, which are manifest in its language. Language has shared meanings, which form the basis of a discourse community. Mentors model the community's language norms and practices and transmit knowledge of the

discourse community to novices. Members of a discourse community sometimes use jargon and slang to exclude outsiders, but most often jargon is used to increase the community's efficiency or to label or connect ideas. Novices learn to write in their disciplines by their involvement in authentic activities such as co-authoring a research paper.

2. Proposition: Research supervisor team members will inform students about the nature of their respective discourse communities by modeling language selection and use during the co-authorship process. Novices will use their co-authorship experiences to help them become more proficient writers in and of science.
3. Interpretive principles: Just-in-time teaching, shared meaning, language use/jargon, authentic enculturative activities, and adherence to discourse community norms.

Interpretive Frame #7: Dynamics of Collaborative Groups – Co-authoring Teams (RQ #2, #3)

1. Assumption: Novices are expected to assume certain roles within the research team; however, these roles change on occasion and over time. They also are expected to show loyalty and respect for the discipline's culture, history, and status. All team members are expected to demonstrate academic civility, that is, to respect one another and to work to build mutual trust, while advocating different interpretations and participating in scientific debate. Even in the most egalitarian laboratories, the team member with the highest academic status or the grant authority holds most if not all of the power; but knowledge and information are also associated with power.
2. Proposition: Role reversal may be apparent, depending on the topic being discussed. All team members are expected to show loyalty for their discipline and trust in and respect for other team members. Power differentials based on academic standing are likely to be apparent, but the collaborative climate of co-authoring and distributed research assignments tend to dilute many of the traditional power moves.
3. Interpretive principles: Disciplinary culture, academic civility, role reversal, loyalty, respect, trust, power, and academic status.

Assertions

The interpretive frames were used to extract data from questionnaires, draft manuscripts, referees' comments concerning submitted manuscripts, team meetings, and

e-mail interviews relating to: (1) the writing processes team members' report to use and those they actually use in practice; and (2) the beliefs team members' report to hold, and those they actually exhibit, concerning science literacy, the nature of science, the role of writing in science, scientific expertise, the expert science writer, enculturation into the scientific research community, and the collaborative dynamics of the co-authoring teams. Final e-mail interviews were similarly processed and data extracted pertaining to the beliefs that team members report to hold about the role co-authorship in helping them become expert science writers. The following four assertions comprise interpretations of these data. The assertions are organized in the order of the three research questions that guided the design and implementation of this study:

1. What are the activities and processes inherent in the co-authorship of research documents?
2. How do the graduate student's or post graduate student's and the research supervisor's beliefs about writing agree or disagree?
3. Does co-authorship help the student become an expert science writer?

Assertions appear in **bold face**, authors' elaborations are in normal type, and evidence (illustrative quotes, field notes, textual artifacts, discussion examples, etc.) are in *italics*.

Assertion #1a: Several activities and processes are common across all co-authorship teams. Aspects of scientific literacy are inherent and evident in these processes, as are elements of scientific and writing expertise, facets of enculturation into scientific research and discourse communities, and the dynamics of collaborative groups.

All members of the writing teams decided when to write and what to write based on their confidence that their science was solid and worthy of publishing. Students relied on the opinions of their supervisors.

> Field Note: *Rayne's estimation of whether she should begin writing her results depended heavily on Cotton's opinion. As her research supervisor, Cotton helps her judge the rigor of her work, the worth of her findings and their readiness for publication, and the journal to which she should submit*
>
> Daniel: *So far my supervisor has been the one with the ideas. I then carry out the research and once we think we have a story developed, I start writing, often re-*

doing the research as I write from a slightly different angle, so as to be consistent with the story, which hadn't been known before.

Victor: *Writing is the final part of what can be regarded as research, which normally consists of (1) idea, (2) literature review – what has been done so far, (3) research (running models, processing data), (4) writing the paper – I consider my results are publishable; this is not always the case.*

Alexander: *After I get the impression I reached some robust conclusions, I start the writing process.*

All but one of the co-authors used either a mental or a written outline to organize their results before writing. The supervisors stressed pre-writing activities, but each student appeared to have a somewhat different approach to writing.

Daniel: *[I don't] use a formal outline; [I use a] core dump method...I simply sit down, write more or less straight in one go, and then do extensive editing, pasting, cutting, switching, adding, et cetera. The idea is to get a frame to build around. The process differs only really for longer things, such as journal articles: in that case I tend to segment the process into the various sections (for example, introduction, data, and method, results, discussion, and then try to synthesize them.*

Both research supervisors used a think-aloud protocol or an embellished written outline of the research results to develop the storyline for the paper and to model the metacognitive awareness and executive control required by science writers. Cotton believed the most valuable part of the co-authoring process was the amount of talking they did about the experiments. Alistair stressed brainstorming and organizing as pre-writing techniques.

Cotton: *It's a way of formalizing the experiments; the holes are always evident when you try to present a story with figures and tables, et cetera.*

Alistair: *I start by figuring out who my audience is; brainstorm bullets that represent sections or paragraphs I want to include; order bullets so the piece follows a theme; and start writing. This is pretty consistent for everything I write.*

The supervisors used data tables, computer models, graphs, and figures as a basis for these activities, and to illustrate that the practical development of a research paper may

not follow the traditional steps in a scientific inquiry. Alistair and Cotton used these techniques not only to organize their own thoughts, but also to teach the students how to construct papers around a central theme represented in figurative results.

All co-authors reported doing literature searches both before and during their writing. Alistair and his students reported doing library research on the topic before and during their writing.

> Alistair: *I am aware of the literature when I start but only write this bit at the end. As you write, you always find issues that need to be further explained.*

All co-authors reviewed and revised their work. The self and peer review helped them ensure their science ideas were clear and helped them better understand their science. Thus, review and revision were considered a critical part of writing, and, as a result, substantial time was allotted to these activities. Alistair's revision of Alexander and Ryo's conclusion demonstrated the simultaneous use of certainty and humility in science writing.

> Textual Artifact (Original Conclusion): *We suggest that active ice sheet model components are included in simulations of past and future climate change, particularly if changes of the Atlantic overturning are considered.*
>
> Textual Artifact (Alistair's conclusion): *We suggest that possible answers to these questions will only be obtained from simulations using coupled atmosphere-ocean general circulation models that must incorporate comprehensive continental ice sheet models, particularly if changes of the Atlantic overturning are to be considered.*

In Cotton's edit of Rayne's draft, Cotton and Rayne focussed more on the science: they identified the protein as a microbial chaperonin. Cotton helped Rayne better develop a line of reasoning that sets the stage for the final sentence, which is the key finding of the paper. The following two versions of Rayne's paper (6th edit) were taken from the last paragraph of the introduction:

> Textual Artifact (Rayne's version): *Identification of influential midgut proteins using standard protein chemistry is impossible when analyzing a complex mixture of molecules, in this case both insect and microbial in origin. Matrix-assisted*

laser desorption time-of-flight...are the methods of choice for protein identification. Peptide-mass fingerprints (PMF) from trypsin-digested target proteins are used to interrogate protein databases with either mass or sequence information. Using this proteomic approach, we unexpectedly identified the predominant tsetse midgut protein as being a microbial chaperonin.

Textual Artifact (Cotton's version): *Identification and characterization of proteins present in only small amounts of materials, such as tsetse midgut is not easily performed by standard protein chemical techniques. Although molecular biology techniques can be powerful tools for gene discovery, the linkage disequilibrium often encountered between ...can lead to false assumptions about expressed proteins. For this reason, we have used protein microchemical techniques and mass spectrometry to identify major proteins in midguts of teneral Glossina morsitans morsitans. Using this proteomics approach, we unexpectedly identified the predominant tsetse midgut protein as a microbial chaperonin.*

The writing processes described by the co-authors were neither strictly sequential nor discrete: all of the processes were iterative and overlapped. Editing often stimulated the co-authors to return to the planning stage, and, in some cases, to the laboratory or the computer. Alistair noted that, with respect to making new insights into the target science concepts, all of the atmospheric physics teams had similar experiences.

Alistair: *The student wrote a first draft and presented the manuscript to me. I then responded either by recommending more work, rewriting bits, or providing suggestions. In all cases, when one starts to write, one realises that questions arise. In some cases the student found the questions and did more work to answer them. In some cases, after reading the piece, I had remaining questions that required more work, figures, or experiments. These new figures and experiments always lead to a more complete understanding of the problem. The central storyline did not change in the writing but 'what about this' type questions would be addressed.*

Co-authoring can be considered co-constructing of science by the team members. The shared and distributed evidence, knowledge, insights, and abilities coalesce as co-authors put their thinking on paper and provide a common, permanent record for mutual

consideration. These novices and experts would likely say that this process improved clarity and argument; but, in fact, they were constructive and understanding.

Assertion #1b. Academic civility involving personal respect and focussed debate was characteristic of the writing teams.

A dynamic, goal-oriented interpersonal climate was established differently by the research supervisors, but the changing role of expert within the research team was partially responsible for the healthy tension, resulting debate, and knowledge building. Numerous times during the study and in team meetings different people (research supervisor, graduate student, or post graduate student) assumed the lead role in the knowledge building process because of their possession of specific evidence, abilities, experiences, and insights. Other members of the writing team freely relinquished the leadership as someone else demonstrated the needed expertise required to address the current issues, task, or problem. During discussions of revisions to text, co-authors frequently changed roles, with the student becoming the expert. In a meeting with Alexander and Karin, Alistair put himself in the place of a reviewer.

> Alistair: *I would ask if you have this moisture at wind stress feedback, why aren't you using it? ... You caveat [the results] beautifully at the end [but] this is in the wrong place. Be specific about why you did what you did.*

Alistair suggested omitting two entire lengthy paragraphs near the end of the paper, but Alexander opposed this decision. Alistair relented, with the understanding that Alexander would include a "*motivating*" introductory sentence and use an illustrative example.

Cotton often prompted Rayne with questions, thus scaffolding her self-confidence as a scientist and giving her an opportunity to show the scientific expertise she had gained. He maintained that indeed he was not the expert during the entire process.

> Cotton: *Rayne was up on the details of the experiments and had thought about their meaning. I contributed on the organizational aspects; ways to present the materials.*

In the second meeting, Cotton told Rayne it was time for her to begin writing the paper. Her reaction indicated to Cotton that she needed some guidance. He began to question her about what she would include.

Cotton: *So what are you going to say with this paper?*

Rayne: *What am I going to say?*

Cotton: *Yeah, what's the idea?*

Rayne: *I've identified the major proteins in this. So what I have seen in the mid-gut is being that of a GroEL simply because of this.*

Cotton: *Period?*

Rayne: *Period.*

Cotton: *Ok now, if I was to be a devil's advocate, a referee, I would read this and say well there is your 2-D gel spot, all you did was you took that major spot and gave it to the mass spectrometry analyst and bang it is identified as <u>Wigglesworthia</u> GroEL, period.*

Rayne: *No, because all of the rest of the information actually said <u>Sodalis</u>. But had the story been changed, it would have been the other way around.*

Cotton: *So isn't it just worthwhile publishing the one result, just a short note, to the research community? The major protein is <u>Wigglesworthia</u> GroEL period. That is what the information is.*

Rayne: *You probably could do that and then publish a bacteriology paper on <u>Sodalis</u>.*

Cotton: *But do you think that telling the story, you show that the methodology used and the logical reasoning that led you down this path is important?*

Rayne: *Absolutely. And I think it shows how mass spectrometry can be used to distinguish between different species in a protein mixture.*

Cotton: *Yeah, and that things are highly related to each other.*

This discussion helped Rayne decide to write a full-length paper that focused not only on her findings, but also on the methodology she had used. Indeed, Cotton was very proud of Rayne's initiative and critical thinking abilities.

> Cotton: *At one point during the laboratory work Rayne invented an experiment where she measured whether or not the ...bacterium can secrete this [protein] all by itself. ...Logically it should, and it does -- here's the figure to show it.*

Rayne took a risk with her time and also her supervisor's time, and it paid off well.

Rayne noted that she had to do library research throughout her writing because she had to know what was being published in her specialty to augment her claims and evidence, and to speculate what the competition was doing. If it looked like someone was working up to publishing findings similar to hers and might be ready to scoop her ideas, she might consider submitting a short research note rather than a full research paper, in the hope of getting her results into the literature faster. This competition did not extend to the work of her collaborators, however. Rayne showed a great deal of academic civility in considering a co-author. *I really don't want to come out first with my...sequence ...and subtract from the work that she has done. ...I don't want to step on her toes.*

Research supervisors used the authentic co-authoring processes and activities to teach the students about disciplinary culture, audience, language use, and style within discourse communities, and to model academic civility. Revision processes also allowed co-authors to express intrinsic principles such as loyalty, respect, and trust. Power and academic status were apparent in the processes, but they were never wielded with a great deal of force or in a negative fashion. Rayne: *[I am a] giant sponge"*, maintaining that the supportive laboratory environment empowered her to first think and then correct her wayward thoughts, without *"debilitating criticism"*. She greatly valued her relationship with Cotton.

> Rayne: *He was my partner and mentor simultaneously. What he did not understand, I tried to teach; what I could not do, he showed me how to do by example. I know this is unusual in the realm of graduate student experiences and feel very fortunate to be in this situation.*

The issue of ownership was central and contentious in one meeting of Alistair, Alexander, and Ryo. The blunt interactions that followed illustrate the degree of concern and mutual respect that Alexander and Alistair had for each other.

Alexander: *I think generally [Alistair's editing] improves the writing style but I have to say, I really don't want someone who reads the paper, to say, oh that's Alistair's style. ...I mean [if it is published it would be] because one famous guy is on the paper. Even if he is not the first author, everybody thinks it is his paper and the other guy maybe did the work, but Alistair is the one who really did this paper, or had the idea. So I'm going to take all your suggestions and I'll see what a difference they make, but I'm going to rewrite it, in my own style.*

Alistair: *OK, I'll tell you that this paper, as you wrote it, will not be accepted. It would be rejected because of the way it was written.*

Alistair went on to praise the science and try to explain why the style would not be acceptable to [the journal]. He described re-writing the abstract, parts of the introduction, and the concluding sentences.

Alistair: *This is what the editors are going to read. ...They are going to scan through this, but the reviewers are going to read this, that's what gets it into [the journal]. And then they come back and they read the conclusion.*

Alistair clearly had Alexander's best interests at heart when he edited the manuscript, and he tried very hard to convey his reasons for making the changes:

Alistair: *You are trying to get a reputation. This is how you do it. This is the way it is done. ...Your work is good, the next place you go, I mean, you build a reputation by doing the same quality stuff for each institution, and they know it is yours. This is not my style, this is [the journal's] style.*

Alexander agreed that perhaps Alistair was right about the writing style being important, but he could not put the writing before the science. *"It's the science. If it's really something very important, it should be published in Nature even if it's written by someone who barely speaks English."* Alistair assured Alexander that as first author, he had final say in the manuscript. Alexander accepted this saying that while he saw that Alistair's editing had added polish to the paper *"I mean, you have to start somewhere ...but I have the feeling I have to do it my own. I have to, you know, I have to learn for myself right now."* Alistair accepted this with a great deal of equanimity, although he did try once again to explain that the work was still Alexander's and that by accepting his editing suggestions, he was by no means diminishing his role in the co-authorship.

> Alistair: *You can learn through the school of hard knocks, which is the way you are suggesting which is having a paper rejected or you can learn ... from [the collaboration]. If you are going to change it, I would not go back and change the [original draft], but change this [edited version]. And that's perfectly fine, I mean, that's my job...and it will be your job when you get your faculty position. ...My job has a teaching role as well.*

Alexander did relent and the paper was submitted to and accepted for publication in Science. Alistair strongly advocated for a certain style of writing, but he did not insist upon it. These research supervisors might be considered benevolent interlocutors rather than didactic dictators.

Assertion #2: Graduate and post graduate students' beliefs about science and the role of science writing appear to agree with those of their graduate supervisors in terms of the nature of science and the role of writing in science.

The questionnaire results indicated that the research supervisor and graduate or post graduate students did not necessarily have the same beliefs about science writing at the beginning of the co-authoring study. For instance, at the onset, the students acknowledged the influence of audience in science writing; however, during the co-authorship exercise, they became even more convinced of its centrality.

> Daniel: *When you come with an idea for research it tends to be: 'no one has done this before, and any results will be useful.' Once you get the results, it tends to be 'okay, so which of these results here are more important, surprising, and/or coherent for a story.' Writing forces me to focus.*
>
> Victor: *The usefulness of the co-authorship [can] be seen in the way co-authors direct or re-direct his thoughts, so that a seemingly complex physical process could become more understandable.*

Alexander noted that he gained most from the writing experience with his supervisor and from the opportunity to evaluate the science in his papers during the drafting process.

The repeated discussions and written reactions to the draft manuscripts appear to mediate the students' beliefs and usage of science writing and discourse. Co-authors exhibited the habits of mind such as scepticism, openness, and risk taking associated with

an evaluativist view of the nature of science. Most reported that the evaluativist view best described their beliefs about the nature of science. Cotton described himself as being fairly rigid about the necessity of scientific rigour, for instance he described himself skeptical of huge conclusions drawn from small amounts of data. He also expressed openness and curiosity about new ideas and reluctance to remain anchored to old ideas.

> Cotton: *I have gone into a situation really believing and thinking that something is a certain way and then having it completely turned around. And if you can do that, it means that you're not just selling your own personal agenda. You are trying to find out what is going on. Sometimes you have to be very confident to do that, because it overthrows a lot of your work.*

Rayne expressed openness and curiosity similar to Cotton's, describing herself as agreeing most with an evaluativist view of the nature of science noting *"...however, in my own work, I usually become intrigued by what goes AGAINST my hypothesis and seek to understand why a fact refuses to fit."* Cotton and Rayne exhibited evaluative beliefs about the nature of scientific experimentation in biochemistry and microbiology during their planning meetings. Between the first and second meetings Rayne gained an unequivocal identification of the major protein in the tsetse midgut. Cotton called it *"a complete reversal."* but he did not regard it with disappointment. Both researchers were excited about Rayne's finding and acknowledged that getting unexpected results was part of doing science.

Alistair expressed an evaluativist view of the nature of science. *"Science itself is about trying to understand how things work...science always opens more questions than it solves. It's about debate."* Alexander also described himself as evaluativist, noting the postmodern viewpoint was *"senseless"* because it lacked the ability to apply objective measures to an analysis. Karin leaned more toward the absolutist viewpoint (80% absolutist and 20% evaluativist).

> Karin: *The simplest way to find plausible explanations of nature's laws is to deduce them from observations and measurements and as our methods of observation improve over time. Image B [evaluativist] describes pretty well the temporal evolution of sciences. Image A [absolutist] describes the best way I consider Sciences; it omits however the fact that some theories have been found to*

> *be pure theory and could be proved only later when the methods were good enough."* Daniel chose an evaluativist image, noting, *"I would add ...that hypotheses are usually only developed in hindsight. All knowledge is subject to revision, but obviously some things are more sound than others.*

Victor did not agree with any of the images of science, stating, *"I don't even agree that there may be a definite image of science."* Ryo took an evaluativist stance because the word unchanging in Image A [absolutist] did not sound right and Image C [relativist] *"doesn't make sense."*

> Ryo: *I like 'develop' and 'repeated evaluation' in B [evaluativist], but I don't agree 'most evidence the scientist would likely collect would support the existing hypothesis rather than refute the hypothesis.' Even if it is instructive, scientists don't get funding in [the case of] a negative result.*

These novices and expert scientists were naïve realists, believing in the sanctity of scientific fact while at the same time acknowledging the limitations of science and scientists, and accepting what Karin referred to as the *"temporal evolution of sciences."* In light of this conflicted approach to the nature of science (believing in reality, but being unsure about ever achieving an accurate image of this reality), it is not surprising that these modern scientists had difficulty abandoning the language of the absolutist view and that they commonly used words such as 'prove' and 'solve.' However, they also used hedges in their language (oral and written), indicating that they were not prepared in all cases to offer unequivocal conclusions, or declarations of absolute truths, and further evidencing their evaluativist leanings. Beliefs about disciplinary language and intertextuality appeared to be subsumed in the co-authors' beliefs about the constituents of a well-written scientific paper -- good science followed by good science writing. Rayne concluded *"In a nutshell, a well-written scientific article [features] thorough, well-thought-out research explained in an elegantly simple way or format."* Cotton reported that he ensured accuracy and understanding in his science writing first by thinking about what he had written, and second by asking someone in his area of expertise to read the text and offer criticisms and suggestions. Rayne said *"Can ideas ever be accurately or completely understood by those who do not create them?"* Clearly, Rayne realized that constructing personal understanding accomplished one goal, while

bridging the conceptual gap between author and reader is another equally important task to consider if a scientific claim is to be accepted by the academic community.

Clarity, logic, appropriate introduction and stage setting, good explanation and interpretation, and accuracy were mentioned frequently by the participants in their team interactions and interviews, indicating an understanding of good writing in general and good writing within their respective disciplines. Undeniably, considerations of audience and journal selection dominated the discussions of the style of writing and the length of articles. These topics did not supplant science as the primary concern, but they were a close second. Knowledge of the discourse communities and specific audiences helped the co-authors deal with the gatekeepers of the academy, that is, the referees and editors who could reject their science based on the inappropriateness of the style of writing they had chosen. When asked whether writing helped them understand their work, Cotton and Rayne spoke metaphorically of writing as *"helping to expose holes"* in their data, thought processes, or methodologies. Rayne noted, "*Writing usually helps me conceptualize what I am doing in terms of the big picture.*" Co-authors found that writing deepened their understanding of their science by helping them (1) identify inconsistencies or inadequacies in their data, their logic, or their methodologies; (2) focus on essential information; and (3) consider new ideas and alternatives. Writing in these co-authoring experiences fulfilled a constitutive role, as well as a communicative role.

Assertion #3: Co-authoring is an authentic and meaningful experience in learning how to write like a scientist.

Graduate students, post graduate students, and research supervisors reported that these co-authoring activities promoted their critical thinking, increased their science understanding, and enhanced their writing effectiveness. Each writing team identified voids in their data and weak links among claims, evidence, and warrants. The co-authoring experiences helped them construct more compelling arguments about the science. Alexander found the writing process helped him focus on the essentials. *"It forces you to look at your work from a more distant point of view. This almost always leads to a better understanding of research by putting it in a better context."* Ryo noted that he tried to be critical when he read his work and that improved his understanding.

Victor maintained that writing is always part of research: in this instance, it spurred him to read new literature, contact new people, discuss his results, and summarize his new knowledge. Daniel was definite about the role writing played in helping him understand his research. *"It is very easy to get rather focused on narrow issues, and in the end you have solid results on branches of what you were originally planning. Writing the paper forces you to reconsider where all this fits in to the general field.*

"The students also believed the experience, including the tensions, helped them grow as scientists and become more persuasive, thoughtful writers. Rayne's response to being asked whether the co-authorship process affected her writing was both amusing *and eloquent.*

> Rayne*: Did the co-authorship affect my writing? Is a sea urchin covered in spines? My writing is now smoother and more precise. ...My mind has been forced to critically think about the research from the bias of either an external examiner or the general readership instead of only a primary researcher. Thinking this way has given me more insight into how to present the writing and what to include in the writing with regard to content.*

Students learned that experimental inquiry in science, though necessary, was not sufficient – writing was not just the carrier; it was part of doing science. They learned about targeting their writing to a specific audience; specifically, they learned that journal selection affected their rhetorical goals and selection of language.

Unlike many written assignments, especially those that do not include drafting and revising, co-authoring activities were viewed as authentic science tasks by the people involved in the writing teams. The students referred to the value, utility , and creativity of these authentic tasks.

> Ryo: *[I gained new insight] during the research but not from writing. It happened not because I am a co-author, but I am a co-author because it happened."* Rayne described enjoying the creative process. *Ideas would gallop around like wild horses. Taming of those ideas and working them into a professional format alongside a trainer and friend showed me that the process can be somewhat enjoyable and very rewarding as in the end, you are left with a fantastic template from which to mould subsequent papers.*

Negotiating shared meaning, addressing editorial and conceptual feedback, and augmenting arguments with additional evidence and new warrants led to knowledge building as well as improved text. These scientists demanded that they have good science to write about. They did not realise that writing, editing, and revising processes changed the quality of the science as well as the writing.

Discussion

Findings asserted in this study lend support to those of other researchers who studied graduate students engaged in co-authorship with their research supervisors (Belcher, 1994; Chaopricha, 1997; Dysthe, 1999; Prior, 1994, 1995). Co-authorship of research reports in this study provided an opportunity for a cognitive apprenticeship doing and writing science. Students who partook in this experience gained first-hand, authentic knowledge about writing in science and its relationship to constructing knowledge claims, crafting argument, and linking evidence, warrants, and claims. They addressed science concerns, discourse issues, metacognitive awareness, and executive control on an as-needed basis when they encountered authentic problems. Supervisors provided just-in-time tutoring to students with real needs and in the context of real problems. This is teaching and learning at their very best! These students became further inculcated into their respective disciplinary communities because (1) they had the opportunity to submit to and, in some instance, publish their scientific research results in highly regarded peer-reviewed journals, and (2) during the review and revision of texts, they were afforded a chance to demonstrate their burgeoning scientific expertise.

Several activities and processes, such as outlining, drafting, and revising, were common across all writing teams. The research supervisors and students could be considered modern, evaluativist scientists who possessed habits of mind such as curiosity, openness, skepticism, and mindfulness, and thus were most likely to ascribe to a point of view about the nature of science that anticipated different interpretations of experiences, events, and data, but required these claims be verified against evidence and augmented with established science ideas. The participants shared beliefs about good science writing. The quality and worth of the science to be reported was central to their decision to start the writing process and to their selection of a target journal and audience. These

evaluativists did not fully utilize the language of constructivism. They accepted that writing increased clarity, enhanced the arguments, and improved understanding, but credited the evidence for any drastic changes in conception of the underlying science ideas. It is unclear what influenced their choice of language which contained absolutist terms like truth, proof, and scientific method, while ascribing to an evaluativist, naïve realist view of science. One could speculate that they still view these terms to be the traditions and conventions of the science community. Likewise, evidence (observations, measurements, data, ad information) was assigned the highest priority, as an evaluativist view would; but little or no consideration was given to the human interpretation of this evidence in constructing science claims.

Research supervisors demonstrated academic civility and offered their students excellent enculturative opportunities. They were supportive, trustful, and respectful of their students. They did not abuse their power. Students also respected and trusted their supervisors; they deferred to their supervisors' academic position at times, but they were not afraid to put forward new ideas and to accept the responsibility of expert in the group when appropriate. Numerous examples of the changing mantle of expert were evident when talk turned from a discussion of the general domain knowledge held by the research supervisor to a discussion of the specific procedural knowledge and data details held by the graduate or post graduate students. None of the participants shied away from the intellectual tension often inherent in vigorous academic debate. The participants showed themselves to be discerning and progressive learners who wanted to constantly push the boundaries of knowledge in their fields. Clearly, they did not simply accumulate knowledge: they took risks and engaged in the jump-shift progression of knowledge, critical thinking, strategies, and metacognition intrinsic to the careers of expert scientists. The rapport within these research groups was publicly visible, as they socialized together at lunch, breaks, and social events. These people appeared to sincerely enjoy one another and the personal interplay of science ad debate and argumentation.

Indeed, none of these findings is especially surprising. The research supervisors and students in this study were among the brightest and best that contemporary science has to offer. The convergence of beliefs and similarity of processes obvious in this study is expected in the selective research groups developed by senior scientists. It would be

folly to assume anything but exemplary and compatible behaviour from these individuals. The research group is a microworld of academia in which the members provide mutually beneficial and complementary abilities. The dynamics of these two research cultures differed on the surface but were driven by the same desires and motives. All writing-team members realized they were involved in 'real' science, near the leading edge of discovery.

The most interesting finding surrounds the pervasive influence of audience and journal readership in these writers' decisions. Klein (1999) argued that, in the backward search interpretation of writing, expert writers "*elaborate rhetorical goals of a writing task to accommodate the interests and knowledge of their audience, the personae they wish to project and the formal characteristics of the required text*" (p. 243). Irrespective of students' references to '*dumping their results onto paper*,' which could be associated with Klein's spontaneous utterance interpretation, or starting with figures or tables and reverse engineering a detailed argument around them as a research report, which could be associated with Klein's forward-search and genre interpretations, all of these writers demonstrated the ability and desire to transform their findings so as to persuade select audiences about knowledge claims, which is Klein's backward search incarnate.

This study highlights the value of situating writing activities in authentic settings. Novice writers'/students' research and writing abilities were highly valued by their supervisors, and the novices were legimitized as fully contributing co-authors within the research group. Although a valuable tool for learning the mechanics of writing, formal technical writing instruction in universities generally takes place in inauthentic settings and focuses on the communication of general rather than discipline specific knowledge. Thus traditional technical writing instruction has done little to facilitate the novice's enculturation into a discourse community and his or her apprenticeship as an expert science writer.

Research has pointed to the benefits of including authentic writing experiences in technical writing courses (Anderson, et al, 1990; Artemeva, et al, 1999; Caffarella & Barnett, 2000; Foertsch, 1995; Harris, 1990; Smith, 1995; Yore, 2000). The pertinent question is: Who should take the lead in such a course? Ideally, instruction in technical writing would take advantage of the discourse writing knowledge and metacognition of a

skilled technical writer and the domain knowledge and metacognition of a scientist. Unfortunately, this marriage of talents, knowledge, and metacognition is rarely seen in one individual. Indeed, curriculum planners would be more likely to find scientists who have excellent writing skills than technical writing instructors who have extensive science domain knowledge. The challenge then is to seek ways to facilitate collaborative teaching of scientific writing in authentic circumstances (Carle & Krest, 1998; Koprowski, 1997; Rice, 1998). This study suggests that the co-authoring of a research paper could provide an opportunity for further research on this collaboration.

Concluding Remarks

This research provided insight into graduate and post-graduate science students' experiences in writing. It brought to light activities and processes that are effective in helping students become proficient writers in and of science, especially those associated with rhetorical goals and knowledge transformation. The writers in this study learned how their participation in co-authoring could help them select appropriate journals, address audience needs, build knowledge, and inform their scientific practice. Further study in this area could include longitudinal, ethnographic studies of co-authorship, and collaborative teaching of scientific writing in authentic circumstances.

The most exciting findings of this study involved the apparent incongruent relationships between the scientists' use of language and their evaluativist views of science; and the sociocultural dynamics of research groups seeking consensus in their deliberations. These scientists appeared to believe that the science community's gatekeepers, traditions and conventions, influenced by an n absolutist view of science, dictated the language, voice, and style of reporting science. The label and responsibility of expert were transient in these research groups. Even the most junior member of a research team rose to the expert leadership role when the abilities, skills and information she or he possessed were necessary to address the current issue, task, or problem. The desire to make sense of their science and the mutual trust and respect produced a healthy tension and supportive environment. Academic civility in these research groups involved heated arguments about procedures, issues and ideas but never about people and personalities!

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